

SKELETAL, PLUMAGE, AND MACERATION TECHNIQUES FOR
SEPARATING YEAR CLASSES OF BOBWHITE QUAIL
(COLINUS VIRGINIANUS LINNAEUS)

by

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INTRODUCTION

One of the primary steps in the understanding of an animal species is a thorough knowledge of its population dynamics. Accurate information on longevity and age structure of animal populations is necessary to population dynamics studies and the understanding of the biotic community as a whole. Methods of accurately determining year classes are lacking for most species of North American birds and mammals. For many species it is only possible at present to distinguish juvenile from adult individuals. Limited aging techniques combined with tagging and recapture data permit only rough estimations of population structure and dynamics. Aging limitations have been tolerated in population dynamics investigations, especially in studies of birds and mammals which have high annual population turnover. In these species the adult segment of the fall population is very small (10 to 20 percent) and it is assumed that due to rapid population turnover most of these are in their second year of life. Therefore, further segregation of the adult group is considered unnecessary. However, if an animal in such a rapid turnover population survives the first year, one might be justified in assuming its chances of future survival are increased. Insufficient information is available to permit a reliable affirmation to this assumption, but some studies (Emlen 1940, Lack 1946, Robel 1965) have revealed an increasing ratio of adults through the fall and winter seasons in birds with rapid turnover rates. If data collected in these

aforementioned studies are truly representative of the population structure, the increased ratio of adults would have been the result of greater mortality among young-of-the-year. If the greater portion of winter mortality does occur in the young-of-the-year, turnover in the adult breeding segment of the population may be much less than heretofore believed. Therefore, individuals older than two years of age may comprise a relatively large segment of the adult group of such species.

The construction of life tables has been useful for analyses of species population dynamics, but life table analyses are inefficient when based on data grouped into only two age categories, juvenile and adult. Hence, techniques capable of accurately delineating the age of any or all individuals of a population are greatly needed. Such techniques should be capable of delineating the approximate age of at least 90 to 95 percent of the specimens.

At present bobwhite quail (Colinus virginianus Linnaeus)¹ can be separated into only two age categories, juvenile and adult. This paper represents the background and search for aging characters that would permit separation of year classes II and III in the bobwhite quail.

¹Common and scientific names of birds follow A. O. U. Checklist (1957).

REVIEW OF LITERATURE

Several criteria exist which permit determination of the age of wild birds and mammals. Most of these techniques permit separation of young-of-the-year and adults only. A brief review of the more classical works on the aging of mammals and birds follows.

Aging Mammals

Characters most commonly used for aging mammals are pelage, genetalia, eye lens, teeth, skeleton, and body weight. Petrides (1951a) and Sharp (1958) found the color of the tips of guard hairs, and the tail shape and color, useful for separating young and adult gray squirrels (Sciurus carolinensis Gmelin)¹ and fox squirrels (Sciurus niger Linnaeus). Differences in color patterns of pelts were useful to Dozier (1942) for aging muskrats (Ondatra zibethicus Linnaeus). Petrides (1951b) found body weights of cottontail rabbits (Sylvilagus floridanus Allen) closely correlated with age until September of the birth year, after which there was little age correlation. Schofield (1955) found body weights useless for separating juvenile and adult muskrats.

Baumgartner and Bellrose (1943) described stages of genetalia development which facilitated aging of muskrats, and

¹Common and scientific names of mammals follow McSpadden (1947).

Petrides (1949, 1951a) found similar genetalia criteria valuable for aging gray and fox squirrels, and opossums (Didelphis virginiana Kerr).

The weight of the eye lens has been widely used for aging mammals. Lord (1959) first developed this technique for aging cottontail rabbits. By using lens weights he could estimate the age of young cottontails to within 2 months of their actual age, but for adults, the older the specimen the greater the error in age estimation. Tiemeier and Plenert (1964) acquired similar results when working with the black-tailed jackrabbit (Lepus californicus Mearns). Studies of lens weights in other mammals have revealed the method only reliable for aging young individuals (Sanderson 1961, Longhurst 1964).

Tooth development and wear have proved useful for aging mammals. Gier (1947) has described tooth conditions which permit aging of coyotes (Canis latrans Say). The stage of eruption or wear on various teeth permitted satisfactory classification except in very old individuals. Severinghaus (1949) employed dentition differences for separating age classes of white-tailed deer (Odocoileus americanus Erxleben). Various tooth conditions and measurements were described by Alexander (1951), Schofield (1955), and Olsen (1959) for aging of muskrats.

Seasonal annuli deposited in the cementum of caribou teeth (Rangifer caribou Gmelin) were reported by McEwan (1962) to number one less than the approximate age of the specimen in years. Banfield (1960) found indications of annual rings in

caribou antler pedicels but these were unsatisfactory for aging purposes.

The baculum (penis) bone of certain rodents was found to increase in size as the age of the animal increased. Friley (1949a) distinguished four size groups of baculums in river otters (Lutra canadensis Schreber), each related to an age category. Friley (1949b) described baculum measurements for the beaver (Castor canadensis Kuhl), and Petrides (1950a) found baculum lengths and weights reliable for separating sub-adult and adult red foxes (Vulpes fulva Desmarest) and gray foxes (Urocyon cinereoargenteus Screeber). Kirkpatrick and Barnett (1957) found baculum size too variable in gray squirrels for age determinations.

The degree of calcification of the epiphyseal cartilage in long bones has been described for aging cottontail rabbits (Thomsen and Mortensen 1946). The epiphyseal cartilage present in juveniles had become calcified in rabbits over one year old. Sullivan and Haugen (1956), and Kirkpatrick and Barnett (1957) found epiphyseal calcification reliable for aging gray and fox squirrels.

Several skull measurements have been found to reveal age classes in beaver (Friley 1949b). Kirkpatrick and Barnett (1957) found significant correlations between beaver age and skull measurements but extensive overlap in measurements prevented reliable classifications. Skull measurements have been found unreliable for aging mink (Mustella vison Schreber)

(Lechleitner 1954). Measurements of the zygomatic breadth were reported useful for separating sub-adult and adult muskrats by Alexander (1951), but Marshall (1951) found post-orbital width and zygomatic breadth measurements only fair for aging pine martens (Martes americana Linnaeus). Lechleitner (1954) found the presence or absence of a small lateral tubercle on the distal end of the femur indicative of two age groups of beaver while the total femur length showed no relation with age.

In humans, femoral radiographs of women have revealed that the diameter of the midshaft periosteum increases as cortical thickness decreases (Smith and Walker 1964). Hence, the endosteal diameter, periosteal diameter, and cortical thickness were thought to be age related.

Aging Birds

As with mammals, several criteria have been found for separation of juvenile (year class I) and adult (year classes II and over) birds but separation of adult year classes has been largely impossible. Most criteria have been based on incomplete post-juvenile feather molts.

Van Rossem (1925) discovered that the two outer primary wing feathers of juvenile dusky grouse (Dendragapus obscurus Say) exhibited a more faded and ragged appearance and tended to be more pointed at the tip than those of adults. Similar conditions were described in the bobwhite quail (Leopold 1939, Petrides and Nestler 1944). Amman (1944) found the relative

conditions of the outer three primaries useful in aging sharp-tail grouse (Pedioecetes phasianellus Linnaeus) and pinnated grouse (Tympanuchus cupido Linnaeus). However the outer primaries were found not to differ between juveniles and adults of ring-necked pheasant (Phasianus colchicus Linnaeus), and rock ptarmigan (Lagopus mutus Montin) (Linduska 1945, Weeden 1961).

The color and condition of the greater upper primary coverts was found valuable for separation of juvenile and adult bobwhite quail by Leopold (1939), Petrides and Nestler (1944), and Haugen (1957). These small wing feathers had a white or buff colored tip in juveniles in contrast to a dark tip (with possibly a white vane) in adults. Van Rossem (1925) and Bendell (1955) discovered that size of the rectrices differed between young and adult dusky grouse; first year chicks had shorter and more narrow rectrices than adults. Van Rossem (1925) found that yearling dusky grouse could be distinguished from older birds by the relative length of the outer pair of rectrices.

The secondary wing feathers of juvenile woodcock (Philohela minor Gmelin) were found to exhibit more wear and to vary slightly in color from adult secondaries (Martin 1964). Swank (1955) reported that the color of most small wing feathers differed between young and adult mourning doves (Zenaidura macroura Linnaeus). Young birds had a white or light buff tip on wing feathers while adults had uniform slate gray feathers. Overall color patterns of the wing have been found useless for

aging bobwhite quail since individual variations exist even among birds of the same brood (Kabat and Thompson 1963).

Robinson (1957) has found body weight useful for aging very young bobwhite quail. Ages of chicks under 22 to 23 weeks were estimated to within 2 to 3 days of their actual age, but body weight-age relations in older birds were highly unpredictable.

Linduska (1943) discovered that mandible strength in older birds was accurate for separating juvenile and adult pheasants. If a bird could be lifted by its lower jaw it was likely an adult; if the jaw broke the bird was likely a juvenile. A similar technique employing skull strength was described by Westerskov (1956) for aging willow ptarmigan (Lagopus lagopus Linnaeus). The skulls of juvenile birds could usually be crushed by the investigator's thumb, but those of adults usually could not be.

Hochbaum (1942) found external genitalia useful for aging several species of waterfowl. Hanson (1949) described external genitalia characters which differ among juvenile, yearling, and adult Canada geese (Branta canadensis Linnaeus).

Emlen (1936) found a dorsal diverticulum of the cloaca (bursa of Fabricius) quite large in very young American crows (Corvus brachyrhynchos Brehm); progressively smaller in older juveniles; and absent in adults. Hochbaum (1942) and Linduska (1943) have described bursa measurements that facilitate aging of waterfowl and ring-necked pheasants. Kabat and Thompson

(1963) reported good correlations between bursa depth and age of bobwhite quail for quail under 9 months old. Bursa depths of older birds were highly inconsistent with age.

The eye lens weight, used for aging mammals, has also been investigated in birds. Payne (1960) found no increase in the lens weight of house sparrows (Passer domesticus Linnaeus) after birds were 2 months old. Campbell and Tomlinson (1962), and Dahlgren et al. (1964) found no significant increase in lens weight of ring-necked pheasants after birds reached 7 to 8 months of age. Roseberry and Verts (1963) found mean lens weights significantly different among age groups of bobwhite quail, but due to extensive overlap in group ranges, the technique was not considered practical for aging.

Linduska (1943) found that tarsal spurs could be used to age male ring-necked pheasants. Juvenile cocks had smaller, lighter, and more blunt tipped spurs; adults, longer, darker, and more sharply tipped spurs. However Gates (1966) has placed doubt on the accuracy of this technique.

Emlen (1936) used the degree of ossification of the skull to separate young and adult American crows. Cranium ossification was also reported incomplete in the boat-tailed grackle (Cassidix mexicanus Gmelin) until at least February of the first year of life (Selander 1958). Selander and Giller (1960) found the brown-headed cowbird (Molothrus ater Boddaert) and redwing blackbird (Agelaius phoeniceus Linnaeus) can be aged since they do not exhibit complete cranial ossification until

the end of the first year of life.

The developing skull of some birds is slowly overlain by a second bone layer. Nero (1951) discovered that the single layered skull of young house sparrows was gradually overlain by a second layer; the degree of overlay being indicative of specimen age. Complete skull ossification was found in birds 6 to 7 months old.

In studying bone development in the Japanese quail (Coturnix coturnix Linnaeus), Simmons and Pankovich (1963) noted that the primary osteons formed by the initial ossification in the cortex of long bones, are partially eroded away in the formation of new osteons. This process increased the number of partial or secondary haversian systems making up the bone tissue. Since erosion was thought to occur throughout life, it was suggested that the relative number of primary and secondary osteons in bone tissue might be related with age.

Although skeletal x-rays have been utilized for aging mammals, Petrides (1950b) observed no age-related differences in skeletal x-rays of woodcocks and mourning doves. Skeletal x-ray studies of other game birds have not appeared in the literature.

METHODS AND MATERIALS

Two groups of pen-reared bobwhite quail were used as study specimens for this investigation. One group of 100 birds was hatched on July 15, 1962 and the other 100-bird group on

May 29, 1963. No differences in heredity or environmental conditions were apparent so the two groups were assumed to differ in age only. Beginning on June 5, 1963 and at the end of each two-week interval thereafter until January 13, 1965, two birds (one of each sex when sex could be determined externally) were removed from each group and asphyxiated with carbon dioxide gas. Specimens were placed in individual one-point freezer bags, and frozen for subsequent examinations. A total of 163 birds ranging from 7 days to 30 months of age were utilized.

External Measurements

From time to time randomly selected groups of frozen specimens were thawed and a series of measurements as described by Baldwin (1931) were conducted on the beak, leg, and mid-toe by means of a Helios inside-outside vernier caliper. These measurements included length of exposed culmen, length of bill from nostril, height of upper bill at base, total height of bill at base, height of upper bill at nostril, total height of bill at nostril, length of mandible to chin feathers, length of right tarsus, diameter of right tarsus at center, length of mid-toe claw, and diameter of mid-toe claw at base. All measurements were recorded to the nearest 0.01 millimeter. A preliminary group analysis on data from 33 birds indicated that the length of exposed culmen, height of upper bill at base, height of upper bill at nostril, length of tarsus, and length

of mid-toe claw were not correlated with age. Subsequently these five measurements were not taken on remaining birds. The other six measurements were conducted on all specimens. Beak measurements were not recorded when the beak was partially amputated or otherwise deformed (Plate I, Fig. 1).

Plumage

Thirty birds (5 males and 5 females from each of three age groups; 5 to 8 months, 17 to 20 months, and 29 to 32 months) were removed at random from the total sample and body plumage of each was examined. Differences in color patterns and feather conditions were recorded.

The wings of all specimens were removed, injected with 10 percent formalin, and air dried. Each wing was examined and differences in color, condition, and color patterns of feathers recorded.

Tissue Decomposition

To facilitate skeletal examinations, specimens were skinned and eviscerated, and most of the flesh removed with scissors (Plate I, Fig. 2). Both dermestid beetle and water maceration techniques were tried for removal of remaining flesh. Dermestid beetles were unsatisfactory due to difficulty in establishing and maintaining a colony, slowness of flesh removal, and uneven cleaning of the skeletons. Water maceration was more easily controlled and left clean, intact skeletons.

Maceration therefore was used to clean skeletons of all subsequent experimental birds. Water maceration, as used in this study, involved placing 10 to 15 birds into individual cheese-cloth bags and submerging them in a 10 gallon container filled with tap water. Time required for maceration of each batch varied from 2 to 5 weeks. Temperature differences in the laboratory, and differences in initial numbers of decomposing bacteria in the tap water were thought responsible for this variation. Numbered paper tags were attached to each cheese-cloth bag for identification of birds in maceration.

When skeletons were sufficiently clean, they were removed from the containers, further cleaned with a water jet and stiff brush, air dried, and placed in individual boxes (Plate II, Fig. 1). During removal of skeletons the extent of maceration was observed to vary among individual birds. Hence each skeleton was given a numerical rating based on its maceration condition and ratings were later compared with specimen age.

Because maceration rates appeared correlated with specimen age, a more closely controlled decomposition experiment was thought necessary. Chemical decomposition was chosen since pure standard solutions are more easily obtained than are specified kinds and numbers of bacteria for biological decomposition. Sections weighing 19.1 grams were removed from the left breast muscles of each of 61 birds. Each section was placed in 300 milliliters of 10 percent potassium hydroxide and decomposition was observed. With temperature held at

$27.2 \pm 0.5^{\circ}\text{C}$, complete decomposition resulted in 17 to 30 hours. After complete decomposition of muscle tissue, resultant solutions differed slightly in color. Hence, after 36 hours of decomposition the light absorbance of each solution was measured with a Coleman Junior, Model B, spectrophotometer. A wave length of $460 \text{ m}\mu$. was found to reveal greatest differences among solutions and was therefore used for measuring all solutions.

Skeletal Examinations

General Examinations. The skeletons of 103 birds grouped by sex and age class were examined for age related differences in bone structure. Measurements or ratings were conducted on the condition of a small lateral tubercle on the distal end of the femur just proximal to the large lateral condyle, and a similar small tubercle just distal to the head of the femur. Measurements were also made on the width of the median caudal process of the sternum; degree of closure of the right and left nutrient foramen of the sternum; greatest height of the keel (sternal line to sternal crest); number of small anterio-ventral processes on the thoracic vertebrae; number of foramina formed by the fusion of ventral spines of the thoracic vertebrae; roughness or degree of secondary calcification on the dorsal bones of the skull and on the supraorbital margin; width of the dorsal surface of the nasal bone; length of the supraorbital process; size of the mid-dorsal ridge of the sacrum;

degree of closure of the small intertraverse foramina on the dorsal surface of the sacrum; degree of fusion of the pubis with the ischium; and shape of the posterior margin of the ischium.

Cross Sections. The beak, left leg, and left foot were removed from each of 40 specimens for bone structure analysis. Beaks and legs were fixed in 100 milliliters of Zenker's solution for 24 hours and washed overnight in tap water to which a few drops of iodine had been added. Legs and toes were cut into sections approximately 6.3 millimeters in length and decalcified for 5 days in 100 milliliters of McNamara, Murphy, and Gore's solution (Gray 1964). After decalcification, the tissues were washed in 70 percent alcohol for 1 to 2 hours, 85 percent alcohol for 1 to 2 hours, and 100 percent alcohol for 1 to 2 hours. Portions of the tarsometatarsus and phalanges were then embedded in parafin, sectioned in lengths of 15 to 30 μ ., and placed in serial order on 5 x 7.5 millimeter glass slides. Slides were stained by a modified regressive method using Haemotoxylin and an Eosin Y-Azure II mixture, and mounted in a synthetic resinous media. Microscopic examinations of some 1500 sections from the second phalange of the mid-toe were then made. The relative number of primary and secondary osteons, and the average number of osteons from three observations of 0.2 millimeter arcs of the diaphyseal cortex were recorded for each specimen (Plate II, Fig. 2). Endosteal diameter, periosteal diameter, and cortical thickness were

measured with an optical micrometer.

Femur Density. The left femur was removed from each of 103 air dried bobwhite quail skeletons. These were cleaned with a small brush, and oven dried at 90°C for 60 to 72 hours; the time necessary for constant weights. Femurs were then removed from the oven and allowed to cool 20 to 30 minutes in a dessicator. Each bone was subsequently weighed on a Mettler analytical balance and weights were recorded to the nearest 0.00001 gram.

For volumetric analysis femurs were coated with a thin layer of celloidin to seal small foramina leading into the bones. The displacement of 70 percent alcohol by each femur was measured in a graduated cylinder and recorded to the nearest 0.01 milliliter. The femur weight/volume ratio (density) was then calculated.

RESULTS

External Measurements

Statistical analyses of 11 measurements of the beak, leg, and toe of 33 bobwhite quail revealed significant differences among age classes for some measurements (Table 1). Age classes I, II, and III as used in this study were comprised of birds 5 to 8, 17 to 20, and 29 to 32 months of age. Representing age classes I, II, and III were 7, 6, and 3 male and 8, 6, and 3 female birds, respectively.

Analyses of measurements on male birds showed the length of bill from nostril, and diameter of mid-toe claw at base significantly different among the three age classes. Means for length of bill from nostril were 7.78, 8.08, and 8.63 millimeters for age classes I, II, and III, respectively and Fisher's L.S.D. (least significant difference) tests (.05 level) revealed that the means for classes I and III, and II and III were significantly different. Ranges for length of bill from nostril showed considerable overlap between classes I and II but only slight overlap between classes II and III. Means for the diameter of the mid-toe claw were 1.93, 2.16, and 1.96 millimeters for age classes I, II, and III, and L.S.D. tests indicated significant differences between classes I and II, and II and III while I and III were almost identical. Ranges for claw diameter revealed no discrete differences between any of the age classes.

Means of six measurements were significantly different between age classes of females. These measurements were length of bill from nostril, total height of bill at base, total height of bill at nostril, length of mandible to chin feathers, diameter of tarsus, and diameter of mid-toe claw at base. Significant differences existed between classes I and II, and I and III for the first four of the above measurements, but only classes I and II were significantly different for the latter two measurements. Ranges for all six measurements overlapped considerably among age classes.

In addition to the above group analysis comparing birds within the three age classes, a linear regression analysis was performed on six measurements for all 139 birds over 77 days of age (Table 2). Several significant correlations were observed among the measurements themselves. For example the height of bill at base was highly correlated with height of bill at nostril ("r" = 0.6058, males; 0.5347, females). But highly significant age correlations were only found in diameter of tarsus in males ("r" = 0.3387), and total height of bill at base ("r" = 0.3230) and total height of bill at nostril ("r" = 0.5375) in females.

Plumage

A comparison of body plumage on 30 birds representing three age classes disclosed distinct differences among individual birds of like sex. The dark coloration on the neck, nape, and crown of males varied in intensity among some individuals. About one-third of the males examined were very black in these regions while other birds were less dark, some having little dark coloration at all. Most of those very dark were from age class III, but several belonged to class II and some to class I.

Variation was also found in the amount and darkness of barring on the small feathers of the sternal, axillar, and abdominal portions of the ventral feather tract. These feathers had three to five bars on some birds but only one or two bars

on others. The color of the bars varied from deep black in some specimens to light brown in others. Coloration and barring differences, however, were in no way correlated with specimen age.

Differences were evident in the amount of color and barring on both the rectrices and tail coverts. When these conditions were checked against specimen age, there was no apparent correlation except that a slightly greater number of the females with faded coloration on these feathers belonged to age class III. Small variations in coloration were so numerous that no two birds in the entire sample had identical coloration and markings.

An examination of wing plumage failed to show age or sex related differences among adult age classes, but individual differences and differences between juveniles and adults were prominent. Variation existed in the amount of coloration and barring on the distal (outer) vanes of secondaries one through six. A majority (7 of 10) of age class III birds had extensive transverse barring on the secondaries but in other age classes there was inconsistency in barring. Variation was also evident in the width of the white band on the tips of the greater primary, greater secondary, and median secondary underwing coverts. But these variations were not correlated with specimen age.

The two outer primaries and the greater primary coverts of age class I birds differed from those on birds in older age

classes. The two outer primaries of age class I birds were more ragged and had more buff coloration than outer primaries of older birds and inner primaries on the same birds. With one exception all birds of age class I had greater upper primary coverts with white or buff tips while adults had dark coverts. One male 236 days old had all dark coverts. The next youngest male with dark coverts was 339 days old and the two youngest females with dark coverts were 325 and 339 days old. Conversely, one male 647 days old had white tipped coverts.

Tissue Decomposition

Subjective ratings for the extent of flesh maceration on birds left in water 2 to 5 weeks disclosed age-related trends (Table 3). Numerical ratings were given for the relative degree of maceration on individuals from the same container, and these varied from 0.5 to 3.5 for increasing amounts of flesh remaining. Rating averages for age classes were 1.5, 2.3, and 3.0 for males and 1.8, 2.1, and 3.1 for females of age classes I, II, and III, respectively. Considerable overlap in ranges for age classes I and II of both sexes was evident. But there was little overlap between classes II and III since only one bird of each sex in age class II received ratings as high as 3.0, the lower limit of ratings for age class III birds (Plate II, Fig. 1). Three young birds under 100 days old (not included in Table 3) all received 0.5 ratings.

Decomposition of breast muscle tissue in 10 percent

potassium hydroxide revealed no age-related differences among birds. An initial sample of 12 birds (4 from each age class) all decomposed at approximately the same rate but after 20 hours of decomposition the remaining solutions varied in color. All four solutions from age class I birds were clear with little to no residue. Three of the four solutions from age class II birds were pale yellow with small bits of residue remaining (0.5 to 1.0 millimeter diameter) while the other solution had a deep reddish color with larger pieces of residue remaining (1.0 to 2.0 millimeter diameter), as did three of the four solutions from age class III birds. The one remaining solution for class III was like the majority for class II, pale yellow with small bits of residue.

A larger sample of 61 birds was subsequently processed in 10 percent potassium hydroxide and after 20 hours of decomposition solutions revealed a wide series of color gradations. Light absorbance of each solution was measured with a spectrophotometer. Readings varied slightly between solutions from birds of different age classes, and the ranges of these measurements overlapped between all age classes except classes I and III in females. No linear correlation was apparent when light absorbance was plotted against specimen age (Figs. 1 and 2). Linear regression analyses of light absorbance-age correlation resulted in insignificant "r" values for both males ("r" = 0.199) and females ("r" = 0.092).

Skeletal Examinations

General Examinations. Some of the first 18 bobwhite quail skeletons examined (six from each age class) were found to differ in certain skeletal characters. These characters were measured or evaluated for each of the 103 skeletons (Tables 4 and 5). Differences were noted in presence of femur tubercles, sternal width and foramen closure, height of keel, number of anterior projections and foramina on thoracic vertebrae, skull roughness, nasal width, supraorbital length, presence of sacral ridge, sacral foramina closure, ischiopubic fusion, and shape of posterior ischial margin. Only skull roughness was obviously correlated with age in both sexes. Means of other evaluations within the three age classes revealed additional age relationships (Table 6).

The rating scale for the presence of proximal and distal tubercles on the femur was from 0.0 when tubercles were absent, to 2.0 when tubercles were prominent. Mean ratings for the presence of a proximal lateral tubercle were 1.43, 1.50, and 2.00 for age classes of females, revealing high incidence of this tubercle in all age classes and an increase in incidence with age increase. Mean ratings for the proximal lateral tubercle were 0.67, 0.17, and 1.00 for age classes I, II, and III of males, indicating an overall lower incidence of the tubercle in males, especially those of age class II.

The distal femoral tubercle was always present in males of age class I (2.00 average), usually present in males of age

class II (1.50 average), but never present in males of age class III (0.00 average), disclosing a disappearance of the tubercle with increased specimen age. The distal tubercle was absent or only rudimentary in all three age classes of females (0.60, 0.57, and 0.25 averages).

Means of sternum width were equal for all three age classes of both sexes (2.00 millimeters), except for slightly lower averages for age class I males (1.67) and age class II females (1.71). The right sternal foramen was open in one-half the male specimens of age class I (1.00 average; 2.00 = open, 0.00 = closed), seldom open in age class II males (0.33 average), and never open in age class III males (0.00 average). The right sternal foramen was closed on all females in the three age classes (0.00 averages). A left sternal foramen was frequently open in males of age classes I and III (1.33 and 1.00 averages; 2.00 = open, 0.00 = closed), but seldom open in males of age class II (0.33 average). The left sternal foramen was closed in most females examined (0.40, 0.43, and 0.50 averages).

The average keel height was about equal for age classes of both sexes. There was no apparent age-related trend in males (16.24, 15.73, and 16.75 millimeter averages), but a slight trend in females (15.73, 16.24, and 16.24 averages). The number of antero-ventral processes on the thoracic vertebrae averaged 1.50, 1.17, and 3.00 for males in age classes I, II, and III, indicating more processes in older birds. The number

of anterio-ventral processes averaged 2.00, 1.43, and 1.25 for females in age classes I, II, and III, respectively, indicating fewer processes in older birds. The number of foramina formed by fusion of ventral spines of the thoracic vertebrae averaged 1.50, 1.83, and 2.00 for male age classes, and 2.00, 2.20, and 2.25 for female age classes, disclosing more foramina in older birds of both sexes.

The dorsal surface of the skull was found to vary in roughness among birds and ratings of from 1 for smooth to 4 for rough were assigned to each bird. Averages of ratings given males revealed generally smooth skulls for age class I birds (1.17 average), more roughness in age class II birds (2.17 average), and generally rough skulls on age class III birds (3.50 average). This revealed a direct increase in skull roughness with specimen age. However, averages for all three age classes of females were similar (1.20, 2.00, and 1.75 averages). The supraorbital process was also evaluated for roughness with ratings of 1 through 4. Average ratings for age classes were slightly rough for age class I males (1.83 average), moderately rough for age class II males (3.17 average), and rough for age class III males (4.00 average). Average ratings revealed a slightly rough condition on skulls of all three age classes of females (1.60, 2.71, and 2.75 averages).

Averages for nasal width and supraorbital length varied slightly among age classes of bobwhites. Nasal widths averaged 5.33, 5.08, and 5.84 millimeters for male age classes and 5.08,

5.33, and 5.58 millimeters for female age classes, disclosing a linear increase with age in females. Supraorbital lengths were greater for older age classes of both sexes (males = 3.81, 4.32, and 4.56; females = 4.06, 4.32, and 4.56), and averages for females and males were equal in classes II and III.

The mid-dorsal ridge of the sacrum was present in most males of age class II (1.83 average; 0 = absent, 2 = present), but in only some specimens of age class I (0.83 average) and III (1.00 average). This ridge was seldom present in age class I females (0.40 average), but frequently present in females of older classes (1.14 and 1.00 averages). The small sacral foramina were more nearly calcified over in older birds of both sexes. Ratings of 1 for open foramina, through 4 for completely closed foramina, revealed generally open foramina for males of age class I (1.50 average), mostly closed for males of age class II (3.00 average), and all closed for males of age class III (4.00 average). The degree of closure ranged from few open to mostly closed for age classes of females (1.80, 2.29, and 2.75 averages).

The percent of lateral fusion between the ischium and pubis bones disclosed no age-related trends. Average percentages for age classes I, II, and III were 32, 26, and 30 for males and 13, 36, and 17 for females, respectively. Ratings for straightness of the posterior ischial margin (0 = straight, 2 = distinctly curved) disclosed moderate curvature in class I and II males (1.17 and 1.00 averages), and all curved margins

in age class III birds (2.00 average). However, all age class I females had straight margins (0.00 average) with some individuals of age classes II and III exhibiting curved margins (0.71 and 0.50 averages).

Cross Sections. An attempt was made to count the number of secondary osteons in cross sections from the diaphyseal cortex of the second phalange of the mid-toe. However this proved virtually impossible since small fractions of some secondary systems remained and blended in with the primary osteons; and, irregularities were common in lamellar layers that disrupted boundaries of primary osteons. These infusions were so numerous that further attempts to quantitatively relate primary and secondary osteon numbers were abandoned. However the average number of osteons of all kinds in 0.2 millimeter arcs of the cortex was obtained (Fig. 3). An inverse linear correlation between average number of osteons and age was evident for both sexes, especially females. Of 16 specimens, one young (less than 450 days) female and two young males had an average of less than six osteons. Conversely only one old (more than 450 days) male and one old female had more than six osteons.

Cortical, endosteal, and periosteal diameters of the second phalange of the mid-toe differed slightly among birds of different ages but due to irregularities in the cortical margins, measurements were considered too variable for reasonable precision and therefore discontinued.

Femur Density. Weights, volumes, and densities of the left femurs of 103 bobwhite quail over 100 days of age were plotted against specimen age (Figs. 4 through 9). Linear regression analyses disclosed significant correlations between femur density and age in both sexes, and femur weight of males was highly correlated with age (Table 7). Femur weight was highly correlated with both femur density and femur volume in both sexes. However, ranges of these measurements overlapped extensively between age classes.

DISCUSSION

A search for character differences that would facilitate separation of year classes of adult bobwhite quail disclosed some curious differences and some promising techniques.

When using artificially propagated and reared animals for research purposes, how similar such specimens (and experimental results obtained from them) are to wild specimens is always of interest, especially if the anticipated applications of results are for wild animals. In this study "stress" factors, if such exist, could have affected the normal morphological and physiological development of study specimens since the experimental birds were conceived by brood quail confined to pens, and subjected to crowded conditions, human contact, and artificial environments and feeds while growing up. Such factors could have caused increased or decreased rates of plumage development and molting, skeletal and muscular maturation, and keratin

growth and wear, any of which could have caused results which may not have been representative of wild bobwhite. However, specimens used were hatched at about the same time of year as wild birds, and major differences in development rates and molting times were not observed. In addition, "stress" may be as great or even greater in some populations of wild bobwhite.

Accurate age data are essential to population dynamics studies. In such studies small errors in estimations of age compositions can have drastic affects on the results of an entire study. Therefore, it is necessary for aging criteria to be highly accurate (90 percent and up).

A series of 11 external measurements taken on the beak, leg, and toe failed to provide reliable methods for separation of age classes. Although there were significant differences in means of some measurements among age classes, the ranges for these measurements overlapped too much to permit separation of age classes with any degree of certainty.

For male birds the averages for length of bill from nostril and diameter of mid-toe claw at base were significantly different among age classes, and for the latter, L.S.D. tests showed most significant differences were between age classes II and III. Length of bill from nostril increased with increased specimen age but the diameter of mid-toe claw at base was larger in age class II birds (2.16 millimeter average) than in age class III birds (1.96 millimeter average). This reduction in claw diameter was also exhibited in older female birds. This

"shrinkage" was possibly caused by increased wear of the keratin in older birds or hardening of the keratin through reduction of moisture in the claw. Nevertheless, extensive overlap occurred between the ranges of these measurements and since age class III included only 3 males and 3 females, aging from these measurements with the available data was concluded unreliable.

For females the averages of 6 of 11 measurements were significantly different between the three age groups but again there was extensive overlap in the ranges and L.S.D. tests indicated no significant differences between age classes II and III, except for the mid-toe claw diameter discussed above.

Of six external measurements taken on the complete age series of 151 fully grown birds, only diameter of tarsus for females and total height of bill at base and total height of bill at nostril for males were found to be correlated with age. These correlations were quite low and as mentioned above, the overlap in age class ranges for these measurements reduced their usefulness as aging criteria. Tarsal thickness was reported to increase with age in ring-necked pheasants (Kimbball 1944) but, as in this study, with too much variation to be reliable for aging purposes. In the present study the variation in tarsal measurements was thought to be more relevant to the stage of scale shedding since loosening of scales large enough to affect measurements was frequently observed. Measurements on birds with large, loosening tarsal scales present

were likely greater than measurements on birds that had just shed these scales when killed.

An investigation of the total length of the mid-toe revealed wide differences among birds of like age and similarities among birds of different ages so a detailed investigation of this character was abandoned. Gullion (1952) however, disclosed mid-toe length to be 86 percent accurate for separating juvenile and adult American coot (Fulca americana Gmelin). But coot reach physiological maturity at an older age than quail and may still be growing at sexual maturity (adulthood). Toe length did seem related with the stature of the specimen since larger adults tended to have longer toes. But body size of adults also seemed unrelated with age. This is supported by Robinson (1957) who found no relation between total body weight and age of physiologically adult bobwhite quail.

At the inception of this study keratin tissue of the beak and claws of birds was thought to grow indeterminately, and possibly wear off at the tips but still increase in diameter with increasing specimen age. If the keratin growth is continuous, there must be wear or flaking off all over the keratin surface to compensate for growth, since only slight age-related changes were noted in this study. The situation in wild birds could be quite different.

Davis (1954) suggested that beak measurements might be unreliable for aging purposes when he found that the length of bill is greater in summer and smaller in winter in certain

passerine birds which are insectivorous in summer and granivorous in winter. He concluded that the increased growth in summer was the result of less wear from the insectivorous diet. However, quail used in this study were pen reared birds and although different type feeds were used from time to time, food type was constant for all birds, and the degree of wear should have been similar. But wild bobwhite may exhibit this differential beak wear.

The beaks of bobwhite quail used in this study were clipped when birds were about 7 days old to prevent cannibalism. Normal regrowth failed to occur in 7 of the 151 birds (4.7 percent) over 100 days old used in this study. Several birds had drastic deformities of the beak which made measurements impossible (Plate I, Fig. 1). These beak clippings could have had more subtle effects on all birds and caused measurements to be nonrepresentative.

One would expect that different measurements taken from the same structure would be correlated. But "r" values for correlation between beak measurements were quite low (Table 2). For example, height of bill had almost no relation to the mandible length to chin feathers on the same bill (males, "r" = 0.0745). Only the two measurements of bill height and the two of bill length showed moderate correlation. This indicates that bill growth might follow no set dimensional growth pattern, and that keratin is laid down (or sloughed off) in a rather erratic manner. But clipping of the beaks of young

birds could have caused such erratic growth.

A comparison of body plumage of 30 birds of three age classes revealed a high incidence of individual variations which were all unrelated with specimen age, except for a tendency of very old males to have darker coloration on the neck, nape, and crown regions. However, since equally dark colorations were observed on some young birds, the phenomenon is concluded undependable for aging purposes.

It is possible that increased melanization was correlated with sexual hormone levels in the bird when it died, and that these darker males were killed during the peak of the breeding season when most male animals have more intense coloration. If older birds are more sexually active than first year breeders, this would explain the greater incidence of darker colors in older males. However, checks against dates of death were not made since plumages were discarded in cleaning the skeletons before this possibility was considered.

Plumage coloration could also have been affected by the type of food eaten by the bird since diet is said to affect pelage brightness and texture in many mammals. But all quail in this study were offered the same kinds of feed. Bobwhite coloration could be only hereditary, and controlled by a large series of genes and alleles such as in the domestic pigeon (*Columba livia* Gmelin) (Levi 1941).

Kabat and Thompson (1963) reported wide variations in bobwhite color patterns which were in no way related with age.

They found variations common even among birds of the same brood, which tends to support a multi-gene theory.

Examination of wing plumage of all 163 birds failed to reveal age-related differences between birds over one year old, but individual differences were common. Similar results were reported by Kabat and Thompson (1963). However, when the kill date of birds was related to the coloration of certain under-wing coverts, there was evidence of a relation between coloration and ages of the individual feathers (time since previous molt).

Birds of age class I had very frayed outer primaries and white tipped upper primary coverts which distinguished them from older birds. Only one bird had an unusual upper covert condition for his age class, a male 647 days old with white tipped coverts. Therefore, in this study a 99.4 percent accuracy was attained for separating juvenile and adult bob-white quail by the upper primary covert method. Leopold (1939) who first described these techniques attained 96 to 99 percent accuracies for separating adults and juveniles. This study supports the high accuracy of these criteria.

The wing feathers on birds of this study were frayed more than is normal in wild birds. This was likely due to birds brushing their wings against the screening when flying about the holding pens. However, there were still sufficient differences in wear and coloration on the outer primaries to permit the high aging accuracy discussed above.

The relative degree of tissue maceration on specimens processed together in the same container revealed age correlations. There was considerable range overlap in ratings for birds of age classes I and II, but all six birds of age class III were rated a 3.0 or over while only one male and one female of the 13 birds in age class II were rated as high as 3.0. Thus, an 89.5 percent accuracy for distinguishing between birds of age classes II and III was obtained. If the error in this character were constant (25 percent of those rated 3 plus belonging to age class II), correction factors could result in greater accuracies. Differential maceration rates are probably related with the general "toughness" condition of flesh of many older animals.

During maceration of specimens a few birds were lost to the study due to deterioration of standard paper labeling tags used. A preliminary test of these tags proved them quite durable in water, so it was concluded that moving of maceration containers for storage caused sloshing of contents and increased tag deterioration. Metal leg bands or labeling tags are recommended for marking birds in maceration tests.

The rate of decomposition of breast muscles in 10 percent potassium hydroxide revealed no relationship with age, although differences occurred in the color and amount of residue in resulting solutions. Differences in color were thought due to differing amounts of myoglobin in the muscle tissue, or to differing amounts of blood remaining in the muscle tissue after

the specimens were killed. Residue differences were possibly due to differing amounts of tendonous tissue being included with the muscle tissue sample.

Since connective tissue of older animals generally becomes more hardened (tendonous), one would expect such tissues to persist longer in decomposition. This would explain the greater residues for older birds obtained here.

Measurements of light absorbance of solutions resulting from muscle decomposition also failed to indicate age differences. Ranges of light absorbance overlapped widely between solutions representing different age classes, and statistical analyses indicated almost complete lack of linear correlation with age ("r" = 0.199, males; 0.092, females).

Additional studies of maceration rates, employing larger samples of birds, seems well warranted.

Of 12 skeletal characters examined on 103 birds, only two, skull roughness and sacral foramina closure, were found to be significantly correlated with age (Tables 5 and 6). As age increased the roughness of the skull tended to increase especially among male birds. This roughness appeared to be caused by additional calcification of connective tissue on the skull, a condition also found to occur in the house sparrow (Nero, 1951). Skulls of younger specimens were rough on the lateral side only, while skulls from progressively older specimens were rough on up to the dorsal mid-line. This indicated that growth of the second layer of bone tissue begins on the

lateral portion of the skull and proceeds toward the dorsal mid-line. Why the second layer was rough and bumpy instead of smooth as the first layer was not determined.

The number and size of sacral foramina tended to decrease with increased specimen age. This was apparently due to reduction in size and eventual complete closure of these small holes due to continued calcification on the sacral surface.

If secondary calcification occurs on several portions of the skeleton, as on the skull and sacrum, until the bird is quite old, the total skeleton weight might increase with aging, and the ratio of body weight to skeleton weight might be correlated with specimen age. However, other factors such as calcium resorption from bones in females during the laying season, would have to be considered.

The averages of several skeletal measurements and ratings were significantly different among the three age classes but in all, including skull roughness and sacral foramina closure, there was extensive overlap in ranges. Therefore, no practical aging criteria could be derived from any of the 12 skeletal characters examined. Likewise, Petrides (1950b) could derive no reliable age-related differences from x-ray examinations of woodcock and mourning dove skeletons.

Kirkpatrick and Barnett (1957) found correlations between beaver age and skull measurements but here also, extensive overlap in ranges prevented reliable age groupings. Skull measurements were also found useless for aging mink

(Lechleitner 1954).

Although presence or absence of femur tubercles showed some relationship with age, there was considerable overlap among ratings for age classes. Lechleitner (1954), however, found the presence or absence of a small lateral tubercle on the distal end of the femur could be used with considerable accuracy to distinguish two age groups of beavers. However tubercles on quail femurs are much smaller than those in beavers and their presence and size is more difficult to evaluate. If microscopic examinations were employed, more substantial correlations between age and tubercles in bobwhite might be achieved.

Since bones of the skull of bobwhite quail failed to separate during maceration in birds over 110 days of age, fusion of the cranium bones was judged to be complete at that age. Selander (1958) found cranium ossification to be incomplete in the boat-tailed grackle until at least February of the first year of life, or roughly 214 days of age.

The number of osteons in the cortex of the second phalange of the mid-toe revealed a definite age relationship (Fig. 3). As age increased the average number of osteons tended to decrease in both sexes. Juveniles could be separated from adults by using an average of six osteons as the dividing line. This resulted in 88 and 81 percent accuracies for aging females and males, respectively. But these accuracies are much lower, and the technique is more difficult than in the presently used

wing feather aging methods. However, if the osteon technique described herein could be supported by more tests, and its accuracy improved, it would be valuable for determining the age of a bird at death from skeletal remains left in the field or as fossils.

Measurements of femur weight, femur volume, and femur density failed to reveal any apparent correlation trends when plotted against age (Figs. 4 through 9). Only femur weight for males was found to be significantly correlated with age but the "r" value (0.370) was quite low. Also, extensive overlap occurred between the ranges of all these variables for different age classes, except between classes I and III, eliminating their reliability in separating age classes II and III (Table 7).

Femur weight was highly correlated with femur volume in both sexes. Femur weight and femur density were also highly correlated, indicating that greater weights resulted from more dense bone tissue rather than just more bone tissue (volume). This is evidenced by the very low correlation between femur volume and femur density.

The averages of femur weight, volume, and density were considerably larger for females than for males. This was unusual since it is normally assumed that calcium is reabsorbed from the bone tissue of females for production of shell for eggs, which would reduce bone weights and densities. However, since female bobwhite only ovulate during a relatively short period each year, and since pen reared birds lay few eggs and

have substantial amounts of calcium in their diets, the amount of calcium resorption may have been insignificant in birds of this study. Also, females may simply be larger on the average than males and, thereby, have larger femurs.

Although no highly accurate techniques were discovered in this study for separating age classes II and III in bobwhite quail, the groundwork laid herein could prove very valuable to future research. Various combinations and indices derived from techniques and characters investigated here could lead to criteria permitting separation of adult age classes of many forms of birds with satisfactory accuracy. It is my hope that this will be accomplished in the near future.

SUMMARY

This study was initiated in June, 1963 as a search for character differences that would permit separation of year classes II and III of adult bobwhite quail. A review of literature revealed a lack of published information on separation of age classes of adult game birds but many criteria were given for separation of juveniles and adults in both birds and mammals.

A total of 163 pen reared bobwhite quail ranging in age from 7 to 913 days were utilized in the study. Eleven external measurements of the beak, leg, and mid-toe revealed changes in these structures with aging. But for each measurement, extensive overlap between the ranges within age classes made the

measurements impractical as aging criteria.

An examination of body plumage from 30 birds representing three age groups failed to reveal significant age-related differences. Examinations of wing plumage of all birds revealed the condition of the two outer primaries and color of the greater upper primary coverts to be 99.4 percent accurate for separation of juveniles and adults. But plumage differences were not found among adult age classes.

Tissue maceration was slow in older birds and rapid in young birds. Subjective ratings of maceration speed in 19 birds yielded an 89.5 percent accuracy for separating birds of age classes II and III. Testing of larger samples under more closely controlled conditions was felt necessary before conclusions on a maceration technique could be made.

Neither decomposition rates of breast muscle tissue in potassium hydroxide nor measurements of light absorbance of the resulting solutions revealed age-related differences.

A thorough examination of skeletons from 103 bobwhite quail revealed 12 characters that differed among individual birds. Of these, only the degree of secondary calcification on the skull and on the small sacral foramina were directly correlated with age. However, the variations within these two factors impeded their use for aging specimens.

Average numbers of osteons in 0.2 millimeter arcs of the diaphyseal cortex of the second phalange of the mid-toe revealed an inverse correlation with age that was 85 percent

accurate for separating juveniles and adults. Most juveniles had more than six osteons and most adults less than six. But due to small sample size and variation in osteon counts for a few specimens, examination of larger samples was felt necessary to establishment of aging criteria. If perfected this technique would be useful for determining the age of birds at death from skeletal remains. No differences in osteon numbers were observed between adult groups.

The weights, volumes, and densities of the left femurs from 103 birds failed to reveal age-related differences. Averages for each of the above measurements were found to be considerably higher for females than for males.

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LITERATURE CITED

Alexander, M. M. 1951. The aging of muskrats on Montezuma National Wildlife Refuge. *J. Wildl. Mgmt.* 15:175-186.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union. Ithaca, N. Y. 691p.

Amman, G. A. 1944. Determining the age of pinnated and sharp-tailed grouse. *J. Wildl. Mgmt.* 8:170-171.

Baldwin, S. P. 1931. Measurements of birds. Cleveland Museum of Natural History, Cleveland, Ohio. 165p.

Banfield, A. W. F. 1960. The use of caribou antler pedicels for age determination. *J. Wildl. Mgmt.* 24:99-102.

Baumgartner, L. L., and F. C. Bellrose, Jr. 1943. Determination of sex and age in muskrats. *J. Wildl. Mgmt.* 7:77-81.

Bendell, J. F. S. 1955. Age, molt, and weight characteristics of blue grouse. *Condor* 57:354-361.

Campbell, H., and R. E. Tomlinson. 1962. Lens weights in chukar partridges. *J. Wildl. Mgmt.* 26:407-409.

Dahlgren, R. B., T. M. Curtis, and F. R. Henderson. 1964. Lens weights of sharp-tailed grouse. *J. Wildl. Mgmt.* 28:853-855.

Davis, J. 1954. Seasonal changes in bill length of certain passerine birds. *Condor* 56:142-149.

Dozier, H. L. 1942. Identification of sex in live muskrats. *J. Wildl. Mgmt.* 6:292-293.

Emlen, J. T., Jr. 1936. Age determination in the American crow. *Condor* 38:99-102.

_____. 1940. Sex and age ratios in survival of the California quail. *J. Wildl. Mgmt.* 4:92-99.

Friley, C. E., Jr. 1949a. Age determination by use of the baculum in the river otter (Lutra c. canadensis, Schreber). *J. Mammal.* 30:102-110.

_____. 1949b. Use of the baculum in age determination of Michigan beaver. *J. Mammal.* 30:261-267.

Gates, J. M. 1966. Validity of spur appearance as an age criterion in the pheasant. *J. Wildl. Mgmt.* 30:81-85.

Gier, H. T. 1947. Coyotes in Kansas. *Kans. Agr. Exp. Sta. Bull.* 393. Manhattan. 97p.

Gray, P. 1964. *Handbook of basic microtechnique.* 3rd ed. McGraw-Hill Publishing Co., N. Y., N. Y. 278p.

Gullion, G. W. 1952. Sex and age determination in the American coot. *J. Wildl. Mgmt.* 16:191-197.

Hanson, H. C. 1949. Methods of determining age in Canada geese and other waterfowl. *J. Wildl. Mgmt.* 13:177-183.

Haugen, A. O. 1957. Distinguishing juvenile from adult bobwhite quail. *J. Wildl. Mgmt.* 21:29-32.

Hochbaum, H. A. 1942. Sex and age determination of waterfowl by cloacal examination. *Trans. North Amer. Wildl. Conf.* 7:299-307.

Kabat, C., and D. R. Thompson. 1963. Wisconsin quail 1834-1962, population dynamics and habitat management. *Wisc. Cons. Dept. Tech. Bull.* 30 pp. 15-16.

Kimball, J. W. 1944. Age gauge for pheasants. *J. Wildl. Mgmt.* 8:263-264.

Kirkpatrick, C. M., and E. M. Barnett. 1957. Age criteria in male gray squirrels. *J. Wildl. Mgmt.* 21:341-347.

Lack, D. 1946. Survival of juvenile birds. *British Birds* 39:258-264.

Lechleitner, R. R. 1954. Age criteria in mink, (*Mustela vison*). *J. Mammal.* 35:496-503.

Leopold, A. S. 1939. Age determination in quail. *J. Wildl. Mgmt.* 3:261-266.

Levi, W. M. 1941. The pigeon. R. L. Bryan Co., Columbia, S. C. 512p.

Linduska, J. P. 1943. A gross study of the bursa of Fabricius and cock spurs as age indicators in the ring-necked pheasant. *Auk* 60:426-437.

_____. 1945. Age determination in the ring-necked pheasant. *J. Wildl. Mgmt.* 9:152-155.

Longhurst, W. M. 1964. Evaluation of the eye lens technique for aging Columbian black-tailed deer. *J. Wildl. Mgmt.* 28:773-785.

Lord, R. G., Jr. 1959. The lens as an indicator of age in cottontail rabbits. *J. Wildl. Mgmt.* 23:358-360.

Marshall, W. H. 1951. An age determination method for the pine marten. *J. Wildl. Mgmt.* 15:276-283.

Martin, F. W. 1964. Woodcock age and sex determination from wings. *J. Wildl. Mgmt.* 28:287-293.

McEwan, E. H. 1962. Seasonal annuli in the cementum of the teeth of barren ground caribou. *Canad. J. Zool.* 41:111-114.

McSpadden, J. W. 1947. *Animals of the world.* Garden City Publishing Co., Garden City, N. Y. 354p.

Nero, R. W. 1951. Pattern and rate of cranial ossification in the house sparrow. *Wilson Bull.* 63:84-88.

Olsen, P. F. 1959. Dental patterns as age indicators in muskrats. *J. Wildl. Mgmt.* 23:228-231.

Payne, R. B. 1960. Growth rate of the lens of the eye of house sparrows. *Condor* 63:338-340.

Petrides, G. A., and R. B. Nestler. 1944. Age determination in juvenile bobwhite quail. *Am. Midland Naturalist* 30: 774-782.

Petrides, G. A. 1949. Sex and age determination in the opossum. *J. Mammal.* 30:364-378.

_____. 1950a. The determination of sex and age ratios in fur animals. *Am. Midland Naturalist* 43:355-382.

_____. 1950b. Notes on determination of sex and age in the woodcock and mourning dove. *Auk* 67:357-360.

_____. 1951a. Notes on age determination in squirrels. *J. Mammal.* 32:111-112.

_____. 1951b. The determination of sex and age ratios in the cottontail rabbit. *Am. Midland Naturalist* 46:312-337.

Robel, R. J. 1965. Differential winter mortality of bobwhites in Kansas. *J. Wildl. Mgmt.* 29:261-266.

Robinson, T. S. 1957. The ecology of bobwhites in south-central Kansas. *Kans. Univ. Mus. Natl. Hist. Misc. Publ.* No. 15. 84p.

Roseberry, J. L., and B. J. Verts. 1963. Relationships between lens-weight, sex, and age in bobwhites. *Illinois State Acad. Sci.* 56:208-216.

Sanderson, G. C. 1961. The lens as an indicator of age in the raccoon. *Am. Midland Naturalist* 65:481-486.

Schofield, R. D. 1955. Analysis of muskrat age determination methods and their application in Michigan. *J. Wildl. Mgmt.* 19:463-466.

Selander, R. K. 1958. Age determination and molt in the boat-tailed grackle. *Condor* 60:355-376.

_____, and D. R. Giller. 1960. First-year plumages of the brown-headed cowbird and redwinged blackbird. *Condor* 62:202-214.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. *J. Wildl. Mgmt.* 13:195-216.

Sharp, W. M. 1958. Aging gray squirrels by use of tail-pelage characteristics. *J. Wildl. Mgmt.* 22:29-34.

Simmons, D. J., and A. M. Pankovich. 1963. Bone development in Japanese quail. *Anat. Record* 147:325-336.

Smith, R. W., and R. R. Walker. 1964. Femoral expansion in aging women: implications for osteoporosis and fracture. *Science* 145:156-157.

Sullivan, E. G., and A. O. Haugen. 1956. Age determination of foxes by x-ray of forefeet. *J. Wildl. Mgmt.* 20:210-212.

Swank, W. G. 1955. Feather molt as an aging technique for mourning doves. *J. Wildl. Mgmt.* 19:412-414.

Thomsen, H. P., and O. A. Mortensen. 1946. Bone growth as an age criterion in the cottontail rabbit. *J. Wildl. Mgmt.* 10:171-175.

Tiemeier, O. W., and M. L. Plenert. 1964. A comparison of three methods for determining the age of black-tailed jackrabbits. *J. Mammal.* 45:409-416.

Van Rossem, A. J. 1925. Flight feathers as age indicators in Dendragapus. *Ibis* 1:417-422.

Weeden, R. B. 1961. Outer primaries as indicators of age among rock ptarmigan. *J. Wildl. Mgmt.* 25:337-339.

Westerskov, K. 1956. Age determination and dating nesting events in the willow ptarmigan. *J. Wildl. Mgmt.* 20:274-279.

APPENDIX

Table 1. Analyses of beak, leg, and toe measurements on 33 bobwhite quail grouped by sex and age. Included are "F" tests for analysis of variance among age classes, and means and ranges where "F" tests were significant.[†]

Variable	F tests	Age class means			Age class ranges		
		2 and 4 df.	I	II	III	I	II
Males (N=7,6,3)							
1	2.87	7.78	14.93 ⁺⁺	8.63	7.07-8.26	7.44-8.58	8.50-8.75
2	6.43*	-	8.08	-			
3	0.90	-	5.18	-			
4	2.47	-	8.20	-			
5	0.41	-	5.43	-			
6	2.89	-	7.66	-			
7	0.84	-	5.78	-			
8	1.14	-	39.45	-			
9	1.12	-	5.33	-			
10	0.45	-	8.04	-			
11	8.44**	1.93	2.16	1.96	1.83-2.03	1.68-2.23	1.80-2.11
Females (N=8,6,3)							
1	1.20	15.10	-				
2	6.55**	7.74	8.26	8.70	7.24-8.50	7.48-8.63	7.97-9.24
3	2.16	-	5.64	-			
4	6.11*	7.79	8.55	8.92	7.47-8.66	7.79-9.45	8.40-9.85
5	3.65	-	5.54	-			
6	5.62*	7.54	8.02	8.15	7.42-7.87	7.74-8.50	8.02-8.32
7	6.19*	5.46	5.95	5.95	5.05-6.09	5.58-6.37	5.48-6.22
8	0.24	-	39.56	-			
9	5.07*	5.18	5.43	5.35	5.03-5.61	5.02-5.58	5.27-5.41
10	2.07	-	7.84	-			
11	4.16*	1.92	2.16	1.95	1.85-2.00	1.83-2.46	1.70-2.08

+ Measurements in millimeters.

++ Only grand means are given where F tests were insignificant.

* Significant at 0.5 level.

** Significant at 0.1 level.

1 Length of exposed culmen.

2 Length of bill from nostril.

3 Height of upper bill at base.

4 Total height of bill at base.

5 Height of upper bill at nostril.

6 Total height of bill at nostril.

7 Length of mandible to chin feathers.

8 Length of right tarsus.

9 Diameter of tarsus.

10 Length of mid-toe claw.

11 Diameter of mid-toe claw at base.

Table 2. Means and standard deviations for beak and leg measurements from 65 male and 74 female bobwhite quail. Simple correlation matrices show relationships among measurements and between each measurement and age.

Measurement ⁺	Means		Standard deviations	
	Males	Females	Males	Females
1 Length of bill from nostril	8.12	8.10	0.615	0.617
2 Total height of bill at base	8.40	8.36	0.541	0.530
3 Total height of bill at nostril	7.91	7.97	0.394	0.414
4 Mandible length to chin feathers	5.76	5.81	0.355	0.094
5 Diameter of tarsus	5.36	5.30	0.198	0.216
6 Diameter of mid-toe claw at base	2.00	1.98	0.109	0.134
7 Age	-	-	-	-

Simple correlation matrices ("r" values).

<u>Males</u>						
(1,2)	(1,3)	(1,4)	(1,5)	(1,6)	(1,7)	
0.4631**	0.3825**	0.5472**	0.2619*	0.1735	0.0711	
(2,3)	(2,4)	(2,5)	(2,6)	(2,7)		
0.6058**	0.0745	0.3142**	0.1030	0.3033*		
(3,4)	(3,5)	(3,6)	(3,7)			
0.1879	0.3326**	0.1872	0.1129			
(4,5)	(4,6)	(4,7)				
0.2345	0.2547*	0.0351-				
(5,6)	(5,7)					
0.2102	0.3387**					
<u>Females</u>						
(1,2)	(1,3)	(1,4)	(1,5)	(1,6)	(1,7)	
0.4891**	0.2790*	0.4585**	0.0259	0.1933	0.1198	
(2,3)	(2,4)	(2,5)	(2,6)	(2,7)		
0.5347**	0.3383**	0.2975**	0.3037**	0.3230**		
(3,4)	(3,5)	(3,6)	(3,7)			
0.3975**	0.2750*	0.0945	0.5375**			
(4,5)	(4,6)	(4,7)				
0.1003	0.1290	0.2595*				
(5,6)	(5,7)					
0.2049	0.2553*					
(6,7)						
0.2202*						

⁺ Measurements in millimeters.

* Significant at 0.5 level.

** Significant at 0.1 level.

Table 3. Subjective ratings for the relative degree of maceration on muscle tissue of 102 bobwhite quail, including averages for each age class.[†]

Males				Females				
Age class	Age (days)	Rating	Mean rating	Age class	Age (days)	Rating	Mean rating	
I	105	0.5	1.5	119	1.0			
	119	1.0		133	1.0			
	133	1.5		147	1.0			
	147	1.5		I	175	1.5		
	161	1.5			189	1.0		
	175	1.0			203	2.5	1.8	
	189	1.0			217	2.5		
	203	1.0			236	1.5		
	217	2.0			248	3.0		
	236	2.5			259	1.0		
II	259	2.0	2.3		287	1.5		
	273	2.0			301	2.0		
	287	1.5			315	1.5		
	301	1.5			329	2.5		
	315	2.0			339	1.0		
	325	2.0			343	1.5		
	329	1.5			357	2.0		
	343	1.5			371	1.0		
	353	2.0			381	0.5		
	371	1.5			399	2.0		
	385	1.5			413	1.0		
	399	2.0			423	1.0		
	423	1.0			437	1.0		
	441	1.5			451	1.0		
	451	1.0			493	2.0		
	455	1.5			497	1.5		
	483	1.5			497	1.5		
II	521	2.0	2.1		507	3.0		
	535	2.0			511	1.5		
	554	2.5			511	1.0		
	566	2.5			521	2.5		
	577	3.0			527	1.5		
	591	2.0			527	2.0		
	619	2.5			539	1.0		
	647	2.0			554	2.5		
	675	2.5			577	2.5		
	689	1.5			591	3.0		

Table 3 (concl.).

Males				Females			
Age class	Age (days)	Rating	Mean rating	Age class	Age (days)	Rating	Mean rating
	703	2.5			647	2.5	
	717	1.5			675	2.0	
	731	1.5			689	1.5	
	745	1.5			703	2.0	
	773	2.5			717	2.0	
	801	2.0			787	2.0	
	815	2.0			801	1.5	
	829	2.5			829	2.5	
	845	2.0			845	2.0	
	857	2.0			857	2.0	
	871	3.0			871	3.0	
III	{ 885 899	3.0 3.0	3.0	III	{ 885 899 913 913	3.5 3.0 3.0 3.0	3.1

† Description of ratings:

- 0.5 All flesh decomposed; individual bones of skull and pelvis separated.
- 1.0 All flesh decomposed; all bones intact.
- 1.5 Intermediate between 1.0 and 2.0.
- 2.0 Some flesh remaining on pelvis and top of head; portions of eye remaining in orbit.
- 2.5 Intermediate between 2.0 and 3.0.
- 3.0 Large amounts of flesh left on pelvis and top of head with small amounts around joints; large portions of eye remaining.
- 3.5 Tissue remaining over most of skeleton.

Table 4. Data on selected skeletal characters from 103 bobwhite quail grouped by sex and age class.[†]

Age class: (days):	Age: P : D	Femur: tubercle	Sternal: width	Foramen: closure	Height: of keel	Thoracic: vertebrae	Skull: rough
				R : L		P : F	D : S
Females							
119	2 2	2	0	0	16.33	3 2	1 1
133	2 2	2	0	0	16.66	3 0	1 1
147	2 2	2	0	0	15.86	3 2	1 1
I	175 189 203 217 236	2 1 2 0 2 0 2 1 2 1	1 2 2 2 3 0 2 2 2 0	0 0 0 2 0 0 0 0 0 0	16.33 15.86 15.55 15.86 15.38	2 2 3 2 3 3 1 2 1 2	1 1 1 2 2 1 1 2 1 2
248	2 0	3 1	0 0	0 2	14.93 16.33	3 2	1 1
259	2 0	3 1	0 0	2 2	16.33	3 2	1 2
287	2 2	3 1	1 2	2 2	15.86	3 2	1 2
301	2 1	3 1	2 2	2 2	16.33	1 2	1 1
315	2 2	1 2	0 0	2 2	17.78	0 0	1 1
325	2 2	2 2	0 0	0 0	15.86	2 2	2 2
329	2 1	1 2	0 0	0 0	15.55	1 1	2 3
339	2 0	3 2	0 0	0 0	15.86	2 2	2 3
343	2 0	3 2	0 0	0 0	15.55	3 2	3 3
357	2 2	2 2	0 0	0 0	15.55	2 1	3 3
371	2 2	2 2	0 0	0 0	15.55	1 2	2 2
381	2 2	1 1	0 0	0 0	15.86	3 2	2 2
385	2 0	1 1	0 0	0 0	15.55	3 2	3 2
399	2 1	2 1	0 0	0 0	15.22	2 2	1 1
413	2 2	1 1	0 0	2 2	16.19	1 1	2 2
423	2 1	1 1	2 0	0 0	17.47	1 0	3 2
427	2 1	1 1	0 0	0 0	16.03	2 0	2 2
433	2 1	1 1	0 0	0 0	15.55	1 0	1 2
451	2 0	3 3	0 0	0 0	15.55	3 0	2 3
493	2 0	2 2	0 0	2 0	15.86	2 2	3 3
497	2 1	2 2	0 0	0 0	15.55	3 2	2 2
497	1 1	1 1	0 0	0 0	16.19	2 2	1 2
507	1 1	2 2	0 0	2 0	15.05	1 0	3 3
511	2 1	1 1	0 0	0 0	16.03	0 1	1 1
511	2 0	3 3	0 0	0 0	15.38	1 0	1 3
II	521 527 527 539 554 577 591	2 1 2 1 1 0 1 1 2 1 1 0 1 0	3 1 1 1 1 2 2 0 2 2 2 2 1	0 0 0 0 0 2 0 0 0 0 0 0 0 1	16.19 16.66 15.86 15.86 16.19 15.55 16.67	2 2 1 2 1 2 3 2 1 2 2 2 0	4 4 1 2 1 2 2 2 4 2 3 1 2 2

Table 4 (cont.).

Age class:(days):	Age :	Femur	Sternal	Foramen	Height	Thoracic	Skull
		tubercle	width	closure	of	vertebrae	rough
		P : D	:	R : L	keel	P F	D S
	647	1 2	2	0 0	16.03	0 2	2 2
	675	1 0	1	0 0	15.86	1 2	1 2
	689	1 0	1	0 0	16.19	2 3	1 2
	703	1 0	2	0 0	15.86	1 2	3 3
	717	1 1	2	0 0	16.85	3 2	2 3
	801	1 1	2	0 0	15.55	2 2	3 3
	829	2 1	2	0 0	16.85	1 1	3 3
	845	1 1	2	0 0	16.19	1 3	2 2
	857	1 0	2	0 0	16.19	3 2	2 2
	871	1 1	2	0 0	16.33	1 2	2 3
III	{ 885	1 0	2	0 0	15.68	1 2	2 2
	899	2 1	2	0 2	16.85	1 2	2 3
	913	2 0	2	0 0	15.55	2 2	1 3
	913	1 0	2	0 0	16.19	1 3	2 3
Males							
	105	2 2	2	0 0	16.19	2 3	1 1
	119	0 0	1	0 0	16.19	3 2	1 1
	133	2 2	1	0 2	16.47	1 2	1 1
	147	0 2	1	0 2	16.66	0 3	1 1
I	{ 161	2 2	1	2 2	16.96	1 2	1 1
	175	0 2	2	0 2	15.86	2 2	1 1
	189	0 2	1	0 2	15.86	1 1	1 1
	203	0 2	2	0 0	16.66	1 1	2 2
	217	2 2	2	0 2	15.86	3 2	1 3
	236	0 2	2	0 0	16.85	1 1	3 3
	273	0 2	2	0 0	15.86	0 2	1 1
	287	2 2	2	0 0	16.19	1 3	1 1
	301	1 2	2	0 0	16.03	2 2	1 1
	315	2 2	2	0 0	16.49	3 2	1 1
	325	0 2	3	0 0	16.85	1 2	2 1
	329	2 2	2	0 0	16.96	1 3	2 2
	339	2 2	1	0 0	15.86	2 3	1 4
	343	2 2	2	0 0	16.03	3 2	2 2
	353	1 1	3	0 2	16.49	2 2	2 3
	371	1 1	3	0 0	16.19	3 3	1 1
	385	2 2	3	0 0	16.66	1 2	2 2
	399	0 1	2	0 0	16.66	1 1	4 4
	423	2 2	2	0 0	16.66	2 2	2 2
	441	2 2	2	0 2	16.33	1 1	1 1

Table 4 (concl.).

Age class: (days):	Age :	Femur	tubercl	Sternal	Foramen		Height of keel :	Thoracic vertebrae	Skull rough
					P : D	width	R : L	P : F	D : S
	455	0	1	3	0	0	16.85	2	2
	483	2	2	2	0	2	16.85	1	2
II	521	0	1	2	0	0	16.33	3	2
	535	0	2	2	2	2	15.86	1	2
	554	0	2	2	0	0	16.49	0	2
	566	0	1	2	0	0	16.19	0	2
	577	0	1	2	0	0	14.76	3	2
	591	1	2	2	0	0	14.69	0	1
	619	1	1	2	0	0	15.38	1	2
	647	0	2	2	0	0	16.66	3	2
	675	1	1	2	0	0	15.86	1	2
	689	1	2	2	0	0	17.47	1	2
	703	1	0	2	0	0	16.33	1	2
	717	1	1	2	0	0	16.19	0	2
	731	1	1	3	2	2	16.49	3	2
	745	1	0	3	2	2	16.66	1	2
	773	1	1	2	0	0	16.19	2	2
	801	1	1	1	0	0	16.66	1	2
	815	1	1	2	0	0	16.03	1	2
	829	1	1	2	0	0	18.23	2	3
	845	1	2	3	0	2	16.19	3	4
	857	1	1	1	0	0	15.86	2	3
	871	1	0	2	2	2	17.47	1	2
III	885	1	0	2	0	2	15.86	3	1
	899	1	0	2	0	0	17.78	3	4

† Explanation of Table 4.

Femur tubercle: P = proximal tubercle; D = distal tubercle;
0 = absent; 1 = very small; 2 = present.

Sternal width: 1 = narrow; 2 = average; 3 = wide.

Foramen closure: R = right; L = left; 0 = closed;
1 = partially closed; 2 = open.

Height of keel: measurements in millimeters.

Thoracic vertebrae: P = number of antero-ventral processes;
F = number of foramina formed by fusion of ventral spines.Skull roughness: D = dorsal surface of skull; S = supra-
orbital process; 1 = smooth; 2 = moderately rough; 3 =
slightly rough to rough; 4 = rough.

Table 5. Data on selected skeletal characters from 103 bobwhite quail grouped by sex and age class.†

Age class:(days):	Age :	Nasal width :	Supra-orbital length :	Sacral ridge :	Sacral foramina :	Ischio-pubic closure :	Posterior ischial margin :
Females							
119	5.22	4.29		2	1	00	0
133	4.78	3.96		1	1	00	0
147	4.78	4.44		2	2	25	0
I	175	5.22	4.29	0	1	10	0
	189	4.78	3.66	2	2	10	0
	203	5.22	3.96	0	2	missing	0
	217	4.93	4.44	0	3	30	0
	236	4.78	4.29	0	1	00	0
	248	4.93	4.29	2	1	missing	0
	259	4.29	4.44	0	1	25	1
	287	4.59	3.96	2	2	33	2
	301	5.56	3.66	0	1	45	2
	315	4.29	3.33	2	2	10	2
	325	4.29	5.22	2	2	10	0
	329	5.56	3.96	2	2	10	2
	339	4.78	4.78	2	1	55	2
	343	4.78	5.56	0	2	10	0
	357	5.22	3.66	2	3	10	0
	371	5.22	3.96	2	1	10	1
	381	4.93	4.78	2	2	05	2
	385	4.78	4.44	0	2	33	0
	399	5.22	3.66	2	1	33	0
	413	6.04	4.29	0	2	33	2
	423	4.44	3.96	1	1	10	2
	427	4.78	4.29	2	1	25	2
	433	5.22	3.66	2	2	40	0
	451	4.78	4.78	1	2	33	0
	493	5.22	4.78	2	4	50	2
	497	4.93	3.96	0	2	30	2
	497	4.78	4.44	2	1	40	2
	507	5.22	4.78	2	2	33	0
	511	4.44	3.66	0	3	50	0
	511	5.56	3.66	0	2	10	0
II	521	6.35	4.44	2	4	33	2
	527	5.22	4.29	2	1	10	0
	527	4.78	3.17	0	2	50	1
	539	4.78	4.78	0	2	33	0
	554	6.50	4.44	2	2	33	0
	577	5.56	4.78	2	1	40	0
	591	4.78	4.44	0	4	50	2

Table 5 (cont.).

Age class: (days):	Age : width :	Nasal: length :	Supra- orbital: length :	Sacral: ridge :	Sacral foramina: closure :	Ischio- pubic: closure :	Posterior ischial margin :
	647	5.22	4.44	2	4	50	2
	675	5.22	3.96	1	2	10	2
	689	4.93	3.96	2	2	50	2
	703	5.56	3.33	2	4	33	2
	717	4.78	4.93	1	4	30	2
	801	4.93	4.59	2	2	50	2
	829	4.93	4.44	2	1	40	2
	845	6.35	3.66	2	1	00	2
	857	5.22	4.93	2	2	00	0
	871	4.93	4.29	0	2	50	0
III	885	4.93	3.96	0	3	33	2
	899	5.56	3.96	0	2	00	0
	913	6.04	4.44	2	2	00	0
	913	5.86	4.29	2	4	33	0
Males							
	105	5.56	4.59	0	1	40	1
	119	4.78	3.17	2	1	33	0
	133	3.96	4.44	2	1	00	1
	147	4.78	4.59	0	2	55	
I	161	5.08	3.66	1	1	25	1
	175	5.56	3.96	1	1	20	2
	189	5.56	3.96	1	2	33	2
	203	4.93	3.66	2	2	33	2
	217	5.56	3.33	0	1	45	0
	236	4.78	4.59	0	2	33	0
	273	4.78	4.59	1	2	45	0
	287	5.22	4.59	1	3	33	1
	301	4.59	4.44	2	2	40	1
	315	4.29	3.96	2	2	40	1
	325	5.07	4.44	2	3	33	0
	329	4.59	4.44	2	2	10	0
	339	5.22	4.93	2	4	missing	1
	343	5.56	4.59	1	2	33	0
	353	5.56	4.78	2	4	55	0
	371	4.93	3.33	2	1	10	2
	385	5.22	3.66	2	1	55	2
	399	6.04	4.59	0	2	00	0
	423	5.07	4.59	0	2	55	1
	441	4.78	3.96	2	2	00	0
	455	6.04	3.96	2	3	55	0

Table 5 (concl.).

Age : class:(days):	Age : width:	Nasal: length :	Supra- orbital: length :	Sacral: ridge :	Sacral: foramina: closure :	Ischio- pubic: fusion :	Posterior ischial margin :
	483	5.56	3.96	0	2	33	2
II	521	4.78	4.44	2	1	25	2
	535	4.78	4.44	2	4	35	0
	554	6.04	4.29	2	2	10	1
	566	4.93	3.96	2	4	50	1
	577	5.22	3.96	1	3	25	1
	591	5.22	3.96	2	4	10	1
	619	5.22	4.44	2	4	33	1
	647	4.78	3.66	0	2	67	1
	675	6.30	4.78	2	4	10	1
	689	5.22	3.96	2	2	35	0
III	703	4.78	3.96	2	4	55	0
	717	5.56	3.96	2	3	20	2
	731	5.22	3.96	1	1	50	0
	745	6.04	4.44	2	1	20	0
	773	5.86	4.29	2	2	50	0
	801	4.78	4.29	2	1	20	0
	815	5.22	3.17	2	1	33	2
	829	5.56	4.29	0	2	33	0
	845	4.78	4.44	2	1	50	0
	857	5.22	4.44	2	2	10	0
	871	5.56	4.44	1	4	55	0
III	885	5.22	4.44	0	4	20	2
	899	6.35	4.78	2	4	40	2

† Explanation of Table 5.

Nasal width: measurements in millimeters.

Supra-orbital length: measurements in millimeters.

Sacral ridge: 0 = ridge absent; 1 = ridge present but flattened; 2 = ridge present.

Sacral foramina closure: 1 = foramina open; 2 = few open; 3 = most closed; 4 = all closed.

Ischio-pubic fusion: estimated percent of pubis fused with ischium.

Posterior ischial margin: 0 = no curve; 1 = partially curved; 2 = curved.

Table 6. Means of measurements and ratings on selected skeletal characters from 103 bobwhite quail grouped by age class and sex.

Character ⁺	Means for male age classes			Means for female age classes		
	I	II	III	I	II	III
(Number of specimens)	6	6	2	5	7	4
P. femur tubercle	0.67	0.17	1.00	2.00	1.43	1.50
D. femur tubercle	2.00	1.50	0.00	0.60	0.57	0.25
Sternal width	1.67	2.00	2.00	2.00	1.71	2.00
R. foramen closure	1.00	0.33	0.00	0.00	0.00	0.00
L. foramen closure	1.33	0.33	1.00	0.40	0.43	0.50
Height of keel	16.24	15.73	16.75	15.73	16.24	16.24
Vertebral processes	1.50	1.17	3.00	2.00	1.43	1.25
Vertebral foramina	1.83	2.00	1.50	2.20	2.00	2.25
D. skull roughness	1.17	2.17	3.50	1.20	2.00	1.75
Supra-orbit. roughness	1.83	3.17	4.00	1.60	2.71	2.75
Nasal width	5.33	5.08	5.84	5.08	5.33	5.58
Supra-orbital length	3.81	4.32	4.56	4.06	4.32	4.56
Sacral ridge	0.83	1.83	1.00	0.40	1.14	1.00
Sacral foramina	1.50	3.00	4.00	1.80	2.29	2.75
Ischio-pubic fusion	32	26	30	13	36	17
P. ischial margin	1.17	1.00	2.00	0.00	0.71	0.50

⁺ Description of abbreviations: P. = proximal; D. = distal; R. = right; L. = left; D. = dorsal; P. = posterior ischial margin. More complete descriptions of characters are given at ends of Tables 4 and 5.

Table 7. Analysis of data from dried left femurs of 103 bob-white quail. Simple correlation matrices show relationships among variables and between each variable and age.

Measurement ⁺	Mean	Standard deviation	Ranges by age class		
			I	II	III
Males (N = 49)					
1 Femur weight	0.3928	0.0540	0.37-0.44	0.36-0.51	0.42-0.49
2 Femur volume	0.4145	0.0469	0.37-0.49	0.36-0.46	0.41-0.45
3 Femur density	0.9454	0.0801	0.86-1.02	0.95-1.16	1.02-1.04
4 Age	-	-	-	-	-
Females (N = 54)					
1 Femur weight	0.4193	0.0450	0.35-0.39	0.35-0.53	0.41-0.45
2 Femur volume	0.4300	0.0342	0.39-0.50	0.39-0.47	0.42-0.46
3 Femur density	0.9752	0.0775	0.88-0.94	0.84-1.13	0.95-1.06
4 Age	-	-	-	-	-

Simple correlation matrices ("r" values).

Males

(1,2) (1,3) (1,4)
0.78857** 0.59317** 0.36986**

(2,3) (2,4)
0.01350 0.24168

(3,4)
0.28819*

Females

(1,2) (1,3) (1,4)
0.70755** 0.68460** 0.24535

(2,3) (2,4)
0.02900- 0.02558

(3,4)
0.31774*

⁺ Weights in grams and volumes in milliliters.

* Significant at 0.5 level.

** Significant at 0.1 level.

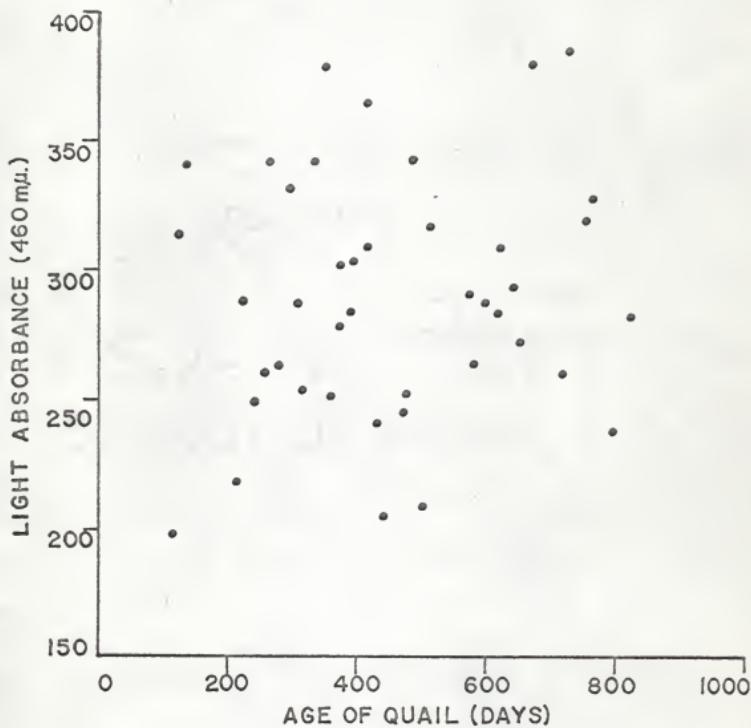


Fig. 1. Light absorbance of decomposition solutions (19.1 gram sections of breast muscles decomposed in 300 milliliters of 10 percent KOH) as related with age in 41 male bobwhite quail.

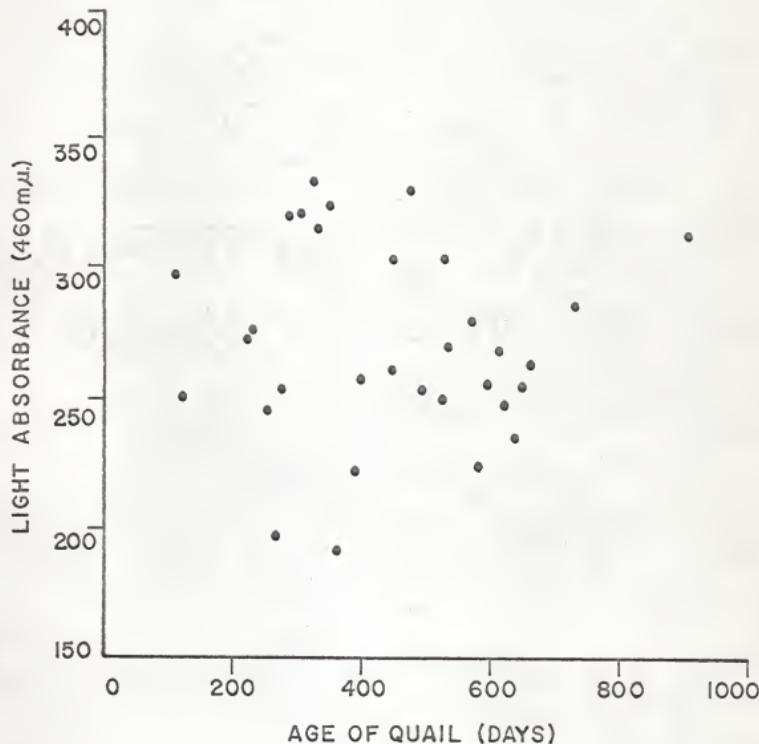


Fig. 2. Light absorbance of decomposition solutions (19.1 gram sections of breast muscles decomposed in 300 milliliters of 10 percent KOH) as related with age in 32 female bobwhite quail.

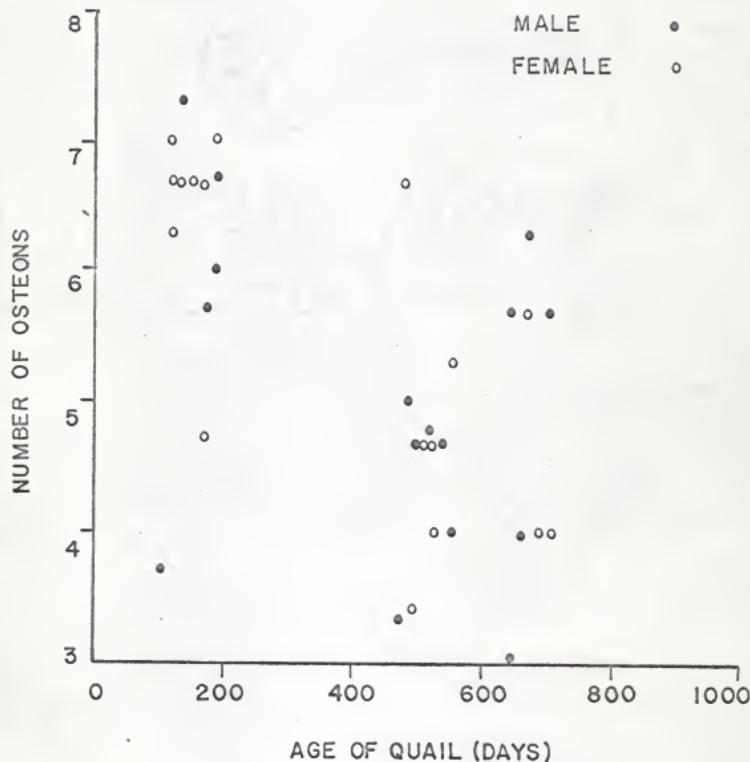


Fig. 3. Average number of osteons in 0.2 millimeter arcs of the diaphyseal cortex of the second phalange of the mid-toe as related with age of 16 male and 16 female bobwhite quail.

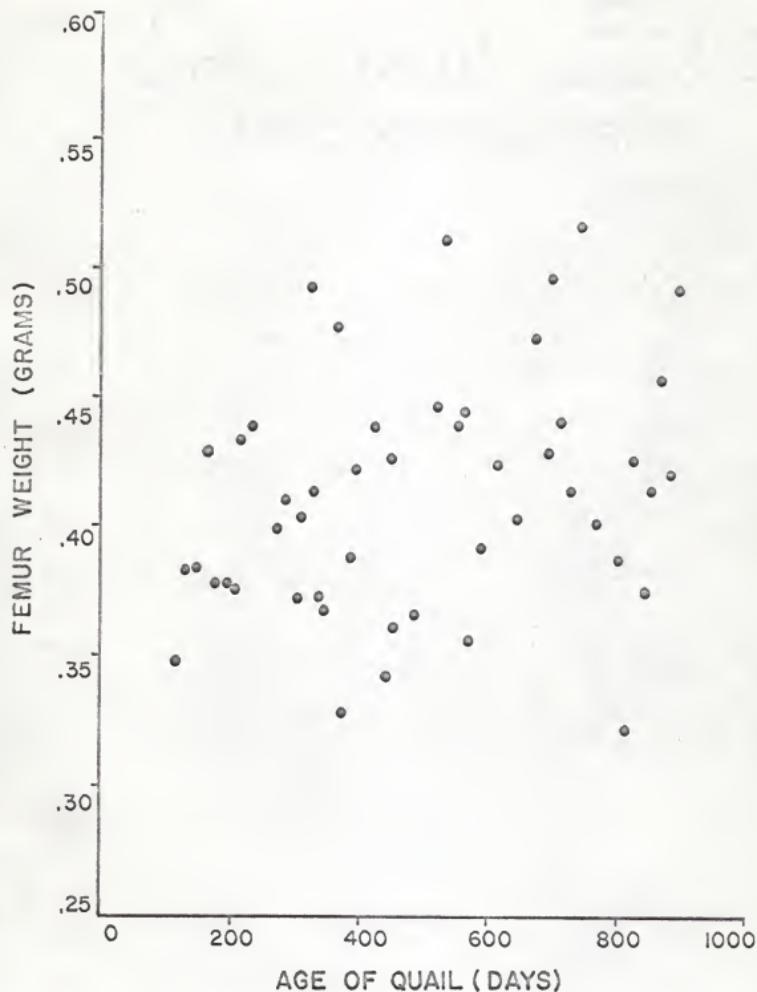


Fig. 4. Weights of oven dried left femurs as related with age of 49 male bobwhite quail.

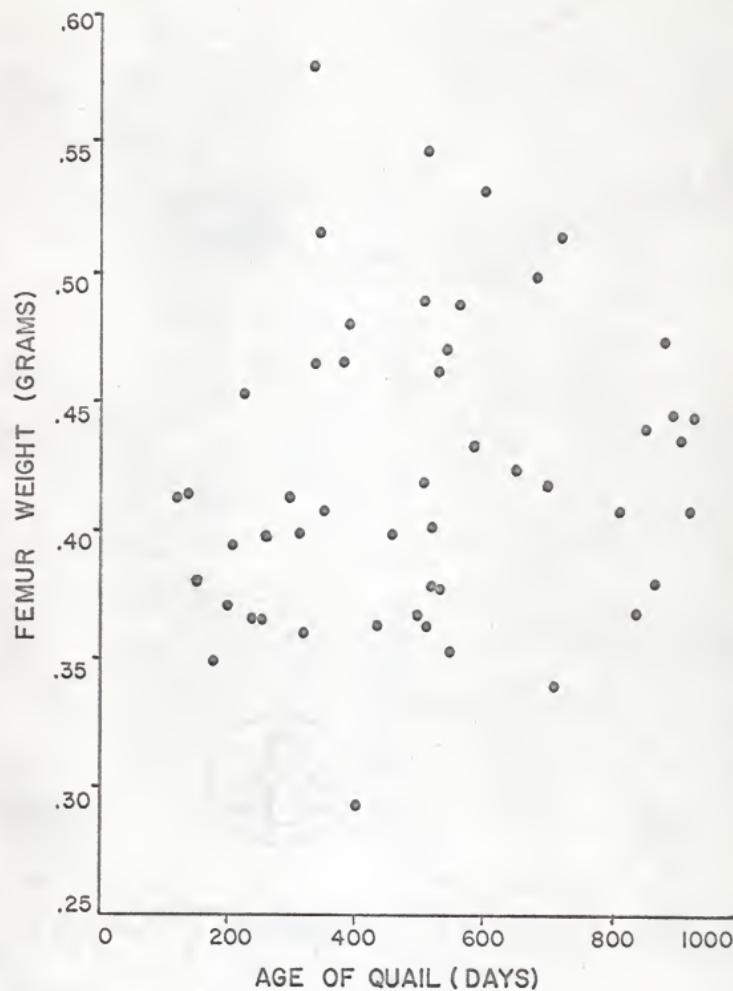


Fig. 5. Weights of oven dried left femurs as related with age of 54 female bobwhite quail.

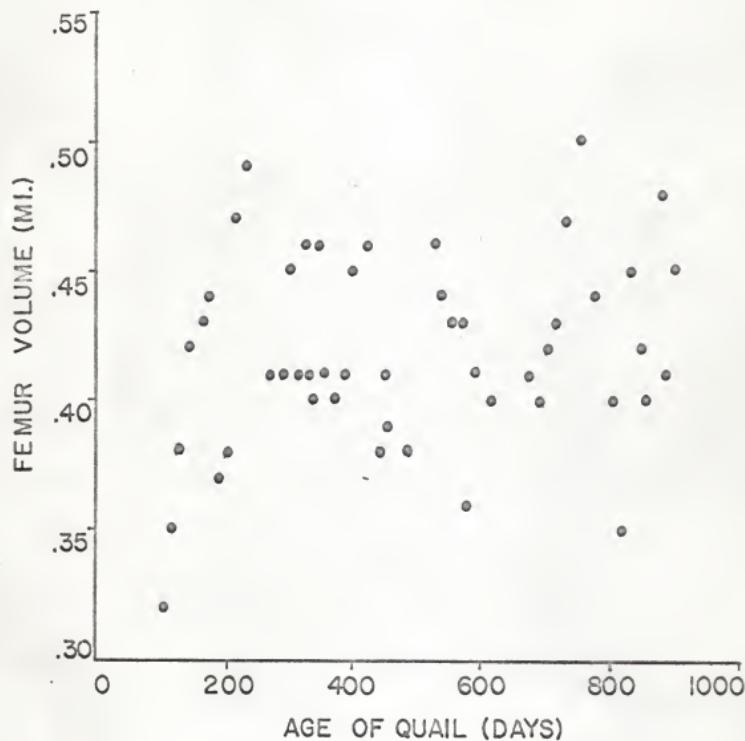


Fig. 6. Volumes of oven dried left femurs as related with age of 49 male bobwhite quail.

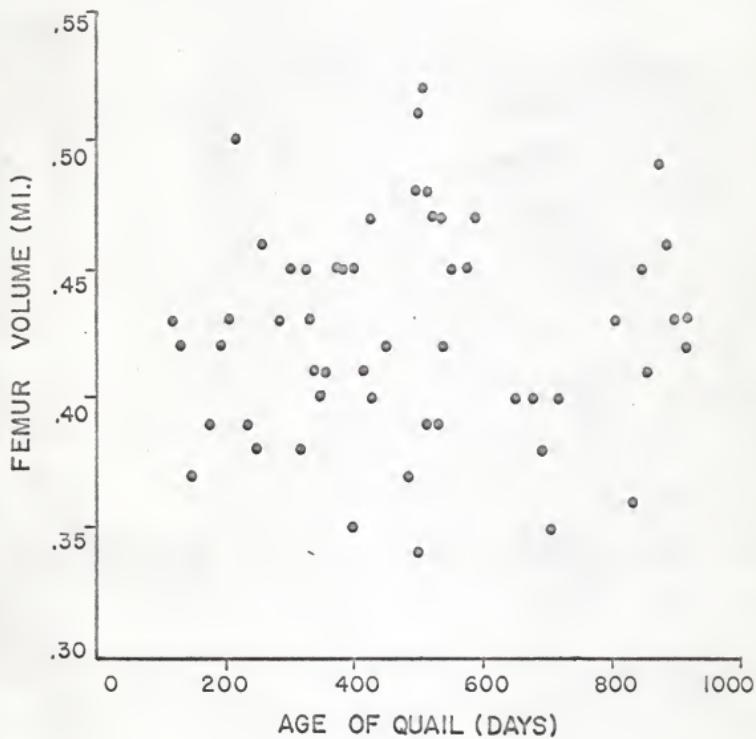


Fig. 7. Volumes of oven dried left femurs as related with age of 54 female bobwhite quail.

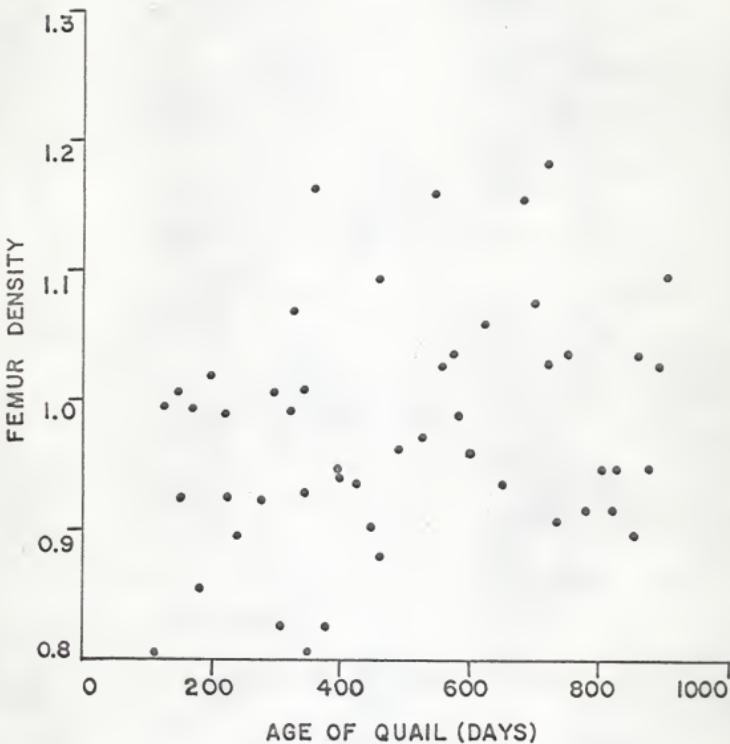


Fig. 8. Densities of oven dried left femurs as related with age of 49 male bobwhite quail.

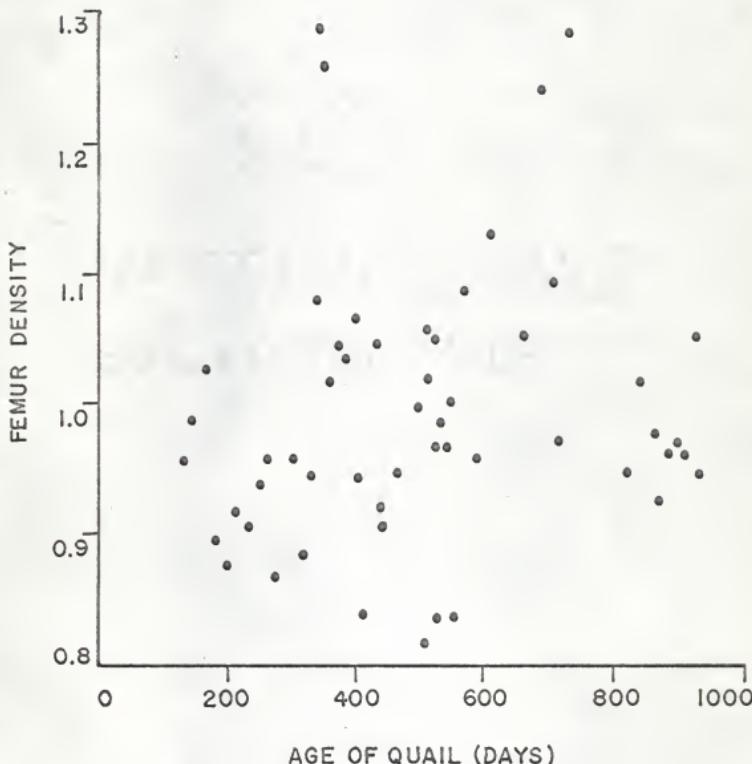


Fig. 9. Densities (gr./ml.) of oven dried left femurs as related with age of 54 female bobwhite quail.

EXPLANATION OF PLATE I

Fig. 1. An adult male bobwhite quail with a deformed beak caused by abnormal regrowth after beak-clipping at 7 days of age. Wings were removed for plumage investigations.

Fig. 2. A bobwhite quail prepared for maceration with feathers and skin, viscera, and most of flesh removed.

PLATE I



Figure 1.



Figure 2.

EXPLANATION OF PLATE II

Fig. 1. Skeletons of a 399 day old female (top) and a 913 day old female bobwhite quail following maceration in the same container for the same period of time. Note flesh remaining on skull and pelvis of older bird (rated 4) and relatively clean skeleton of younger bird (rated 2).

Fig. 2. An approximate 0.2 millimeter arc of the diaphyseal cortex of the second phalange of the mid-toe from a 647 day old male bobwhite quail. Osteon lumens (arrows) with surrounding, overlapping, lamellar layers are shown. (400x).

PLATE II



Figure 1.



Figure 2.

SKELETAL, PLUMAGE, AND MACERATION TECHNIQUES FOR
SEPARATING YEAR CLASSES OF BOBWHITE QUAIL
(COLINUS VIRGINIANUS LINNAEUS)

by

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B. S., University of Kentucky, 1963

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A study was initiated in June, 1963, in search of morphological differences that would enhance separation of year classes of adult bobwhite quail. A total of 163 pen reared bobwhite quail ranging in age from 7 to 913 days were utilized in the study. Three age classes, comprised of birds 5 to 8, 17 to 20, and 29 to 32 months old, were established to represent ages of wild birds in fall.

Eleven external measurements of the beak, leg, and toe were conducted on birds within the three age classes. Six measurements were made on all birds. Measurements included length of exposed culmen, length of bill from nostril, height of upper bill at base, total height of bill at base, height of upper bill at nostril, total height of bill at nostril, length of mandible to chin feathers, length of right tarsus, diameter of right tarsus, length of mid-toe claw, and diameter of mid-toe claw at base. Means of some measurements differed significantly among age classes, and some measurements revealed a linear correlation with age. But extensive overlap in ranges of all measurements between age classes eliminated their usefulness as aging criteria.

A comparison of body plumage was made on 30 birds, 10 from each age class. Extensive individual variations were observed in coloration and barring on neck, nape, and crown feathers, breast and abdomen feathers, and rectrices and tail coverts, but no age-related differences were observed.

Examination of the wings from all study specimens disclosed variations, in coloration on certain underwing coverts,

in coloration of the greater primary coverts, and in coloration and wear on the two outer primaries. Differences in covert coloration were unrelated with specimen age and thought to be correlated with feather age. Primary and primary covert differences were 99.4 percent accurate for separation of juvenile and adult bobwhite quail.

Muscle tissue on old birds was found to decompose slower in water than muscle tissue on young birds. Ratings given for this maceration rate resulted in an 89.5 percent accuracy for separating age classes II and III. Solutions resulting from 19.1 grams of breast muscles decomposed in 10 percent potassium hydroxide were noticed to be different shades of red. But spectrophotometer readings failed to disclose age-specific color differences.

Skeletal examinations of 103 specimens disclosed 12 characters that differed among individuals. These included presence of femur tubercles, sternal width and foramen closure, height of keel, number of anterior projections and foramina on thoracic vertebrae, skull roughness, nasal width, supraorbital length, presence of sacral ridge, sacral foramina closure, ischio-pubic fusion, and shape of posterior ischial margin. Skull roughness and closure of sacral foramina revealed some correlation with age, but overlapping ranges for these measurements among age classes yielded them impractical for aging purposes.

Average numbers of osteons in 0.2 millimeter arcs of the

diaphyseal cortex from the second phalange of the mid-toe were found to be 85 percent accurate for separating juvenile and adult individuals. Juvenile birds usually had an average of more than six osteons; adults less. This technique could prove useful for determining the age of birds at death from skeletal remains found in the field or as fossils.

Analyses of the weights, volumes, and densities of the left femurs from 103 specimens failed to disclose aging criteria. Averages for these measurements were noted to be considerably higher for females than for males.